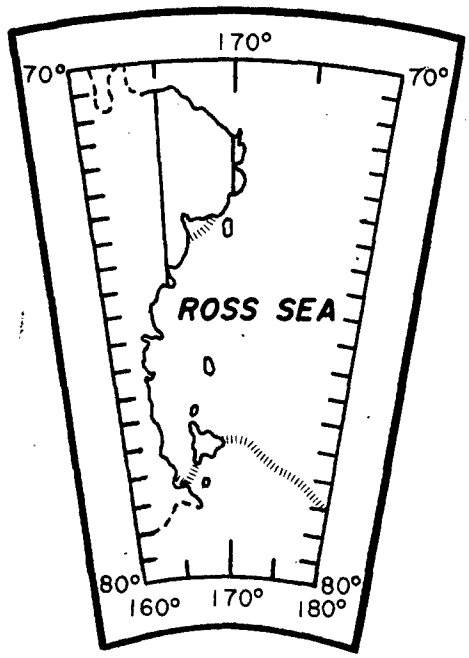
IR NO. 68-64

INFORMAL REPORT

OCEANOGRAPHIC CRUISE SUMMARY ROSS SEA, ANTARCTICA FEBRUARY 1968



SEPTEMBER 1968

NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D. C. 20390

INFORMAL REPORT

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ABSTRACT

During February 1968, a two-phase operation was conducted in Antarctica by NAVOCEANO personnel. The first phase was a study of the currents in the McMurdo Sound region, and the second phase consisted of occupying the annual ice potential stations in the Ross Sea in support of NAVOCEANO's Antarctic Ice Prediction Program.

Current measurements were made by tracking drogues and by mooring self-contained current meter arrays. Preliminary analysis of the drogue data indicates that currents in McMurdo Sound conform generally with the scheme outlined in H.O. Pub. 27 except for a southwest instead of a northwest drift into New Harbor. The data also indicate that the Cape Bird current may have been leaving the coast farther south than described in H.O. Pub 27.

MARTIAL CAR
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This report has been reviewed and is approved for release as an UNCLASSIFIED Informal Report.

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I. PREVIOUS KNOWLEDGE OF THE REGION

A convenient way to discuss the oceanographic features of the Ross Sea is by defining four water masses: Antarctic Surface Water, Winter Water, Antarctic Circumpolar Water, and Shelf Water. Antarctic Surface Water is formed during the summer by dilution and heating of the denser waters. Winter Water and Shelf Water acquire their characteristics during the austral winter. Antarctic Circumpolar Water is a relatively warm and saline subsurface flow from the oceans to the north. Table I lists the approximate salinity and temperature characteristics of the four water masses.

TABLE I. APPROXIMATE SALINITY AND TEMPERATURE RANGES OF WATER MASSES FOUND IN THE ROSS SEA

Water Mass	Salinity Range	Temperature Range
Antarctic Surface Water	33.50 to 34.50 ‰	-1.75 to + 1.50°C
Winter Water	34.15 to 34.45 ‰	-1.90 to - 1.70°C
Circumpolar Water	34.60 to 34.75 ‰	+0.50 to + 1.50°C
Shelf Water	34.75 to 35.00 ‰	-2.05 to - 1.80°C

From NAVOCEANO Pub. TR 118

Information on the current regime of the Ross Sea is not yet sufficient to adequately outline the flow of the various water masses, and with the possible exception of the Hut Point-Cape Armitage area, available information is probably most applicable to the warmer months. Generally, Shelf Water, the densest water mass in the area, appears to flow out of the Ross Sea in two streams, one setting north and the other east. Antarctic Circumpolar Water appears to flow in a southwest direction when entering the Ross Sea. Surface currents close to the Ross Ice Shelf are considered to set west, and close to the sea's western shores, the surface currents are thought to flow north.

The main inflow to McMurdo Sound is considered to be the Cape Bird Current. This current is said to reach Cape Bird as a westerly flow and to turn into the Sound with velocities up to 3 knots (about 150 cm/sec).[1] Then, it is believed to run south along the western coast of Ross Island until it approaches Cape Royds where it is described as joining a strong northwesterly flow entering the Sound from under the Ross Ice Shelf near Cape Armitage. The combined currents then are said to set to the northwest (U.S. Navy Hydrographic Office Pub. No. 27 (formerly H.O. Pub. No. 138)). Direct current measurements made by Gilmour (1963) at a station about 8 miles north-northeast of Cape Armitage and at three stations between Cape Royds and Cape Bernacchi indicated the presence of tidal currents and residual currents with directions in general conformity with the scheme given above; however, the average speeds of these residual currents were less than 15 cm/sec. Scientists have measured currents from fast-ice stations near Cape Armitage. These measurements indicate the presence of an important tidal influence in this region, but the current directions obtained differ in a number of respects. Except for Evans (1965), whose measurements were made in relatively shallow water close to Ross Island, the investigators detected appreciable flows directed towards the Ross Ice Shelf. Gilmour, MacDonald, and Van der Hoeven (1962) and Gilmour (1963) report that there was a residual easterly flow towards the Ross Ice Shelf at all depths during the winter of 1959 and from the summer of 1960 to 1961. During the winter of 1961, Tressler and Ommundsen (1962) found a prominent eastward flow towards the shelf at depths below 300 meters, and they measured a maximum speed of 1.8 knots (about 93 cm/sec) at a depth of 400 meters in this flow. Littlepage (1965), whose measurements span an entire year, found a residual southwest flow at depths from 75 to 275 meters (his deepest sampling depth) except from October to January when a stronger northeast set prevailed. At a depth of 25 meters, Littlepage detected a northwest-southeast oscillatory current with a maximum velocity of about 40 cm/sec. Perhaps, surface manifestations of the northwest cycle of this current are partially responsible for the description of the strong northwest current entering McMurdo Sound from under the Ross Ice Shelf (H.O. Pub. No. 27).

The discrepancies in the currents described by the various investigators may be the result of different sampling locations and/or the possibility of significant temporal changes in the current regime in McMurdo Sound. Some of the results were probably obtained over too short

[1] Direct current measurements made in 1967 by NAVOCEANO personnel at a depth of about 60 meters, between Cape Bird and Beaufort Island, indicate a westward current with an average speed of 1 knot (about 50 cm/sec) and a maximum speed of 2.7 knots (about 140cm/sec). These measurements were made with a self-contained current meter similar to the ones described herein, and they will be included in the report which discusses the measurements made at the 1968 current meter array locations.

a time period to properly account for possible tidal cycles and inertial oscillations.

II. OBJECTIVES OF THE CRUISE

The Naval Oceanographic Office (NAVOCEANO) conducted an oceanographic survey (Operation No. 928034) in the Ross Sea during February 1968. This survey had two objectives: (1) At the request of the National Science Foundation, direct current measurements were to be made in the waters near McMurdo Station (Fig. 1) to provide environmental data needed to support the planned operation of a deep submergence vehicle; and (2) A series of Nansen cast stations were to be occupied in the western Ross Sea (Fig. 2) for ice prediction purposes.

III. NARRATIVE OF THE CRUISE

Four NAVOCEANO oceanographers boarded USCGC WESTWIND (WAGB 281) on 3 February 1968. After planting seven subsurface current meter arrays on 6, 7, and 8 February, the survey team transferred to USCGC BURTON ISLAND (WAGB 283). A total of 22 parachute drogues was launched from BURTON ISLAND between 15 and 19 February. On 16 February, two of the four oceanographers rejoined WESTWIND to assist in the retrieval of the current meter arrays. Six arrays were retrieved. One of the two scientists aboard WESTWIND departed Antarctica on 18 February, and the other returned to BURTON ISLAND on the following day. On 19 February, BURTON ISLAND made an unsuccessful search off Cape Crozier for the last current meter array and then began the annual ice forecast program. After completing the last of 28 ice forecast Nansen stations on 26 February, BURTON ISLAND proceeded to New Zealand. En route, four oceanographic stations were taken along the Macquarie-Balleny Ridge in a joint effort with a Scripps Institution of Oceanography scientist. BURTON ISLAND arrived at Christchurch, New Zealand, on 5 March.

IV. METHODS OF COLLECTION AND ANALYSIS

A. Temperature.

Paired protected deep sea reversing thermometers were used to obtain *in situ* water temperatures. Agreement between the readings of the thermometers in each pair was normally 0.03°C or better after standard corrections were applied.

Normally, mechanical bathythermograph (BT) lowerings were made every 6 hours aboard WESTWIND and BURTON ISLAND. Mechanical BT lowerings also were made at all Nansen cast stations.

B. Depth.

Meter wheel readings, wire angle measurements, and thermometric depth data were used to determine sampling depths.

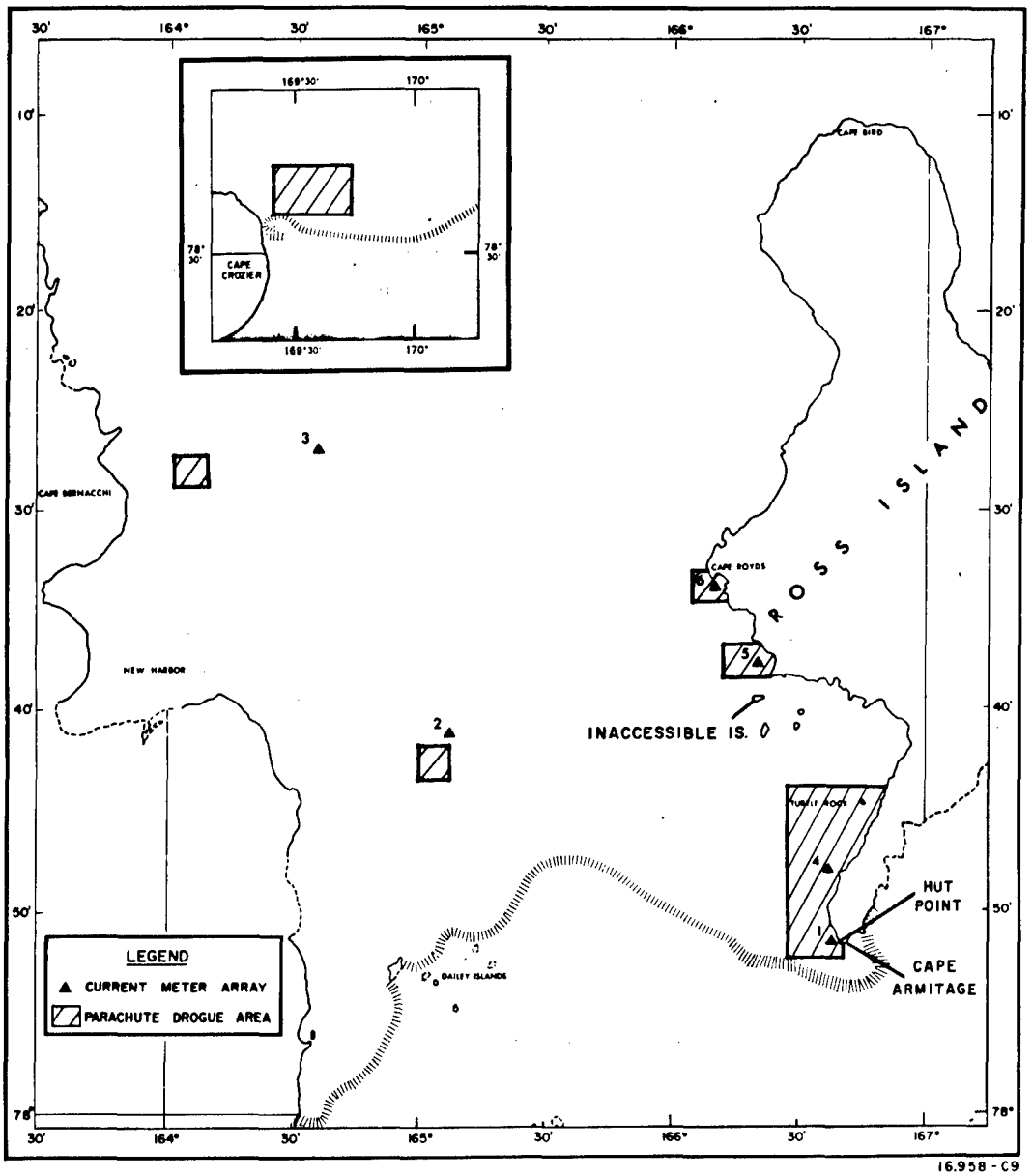


FIGURE 1. CURRENT METER LOCATIONS AND PARACHUTE DROGUE AREAS

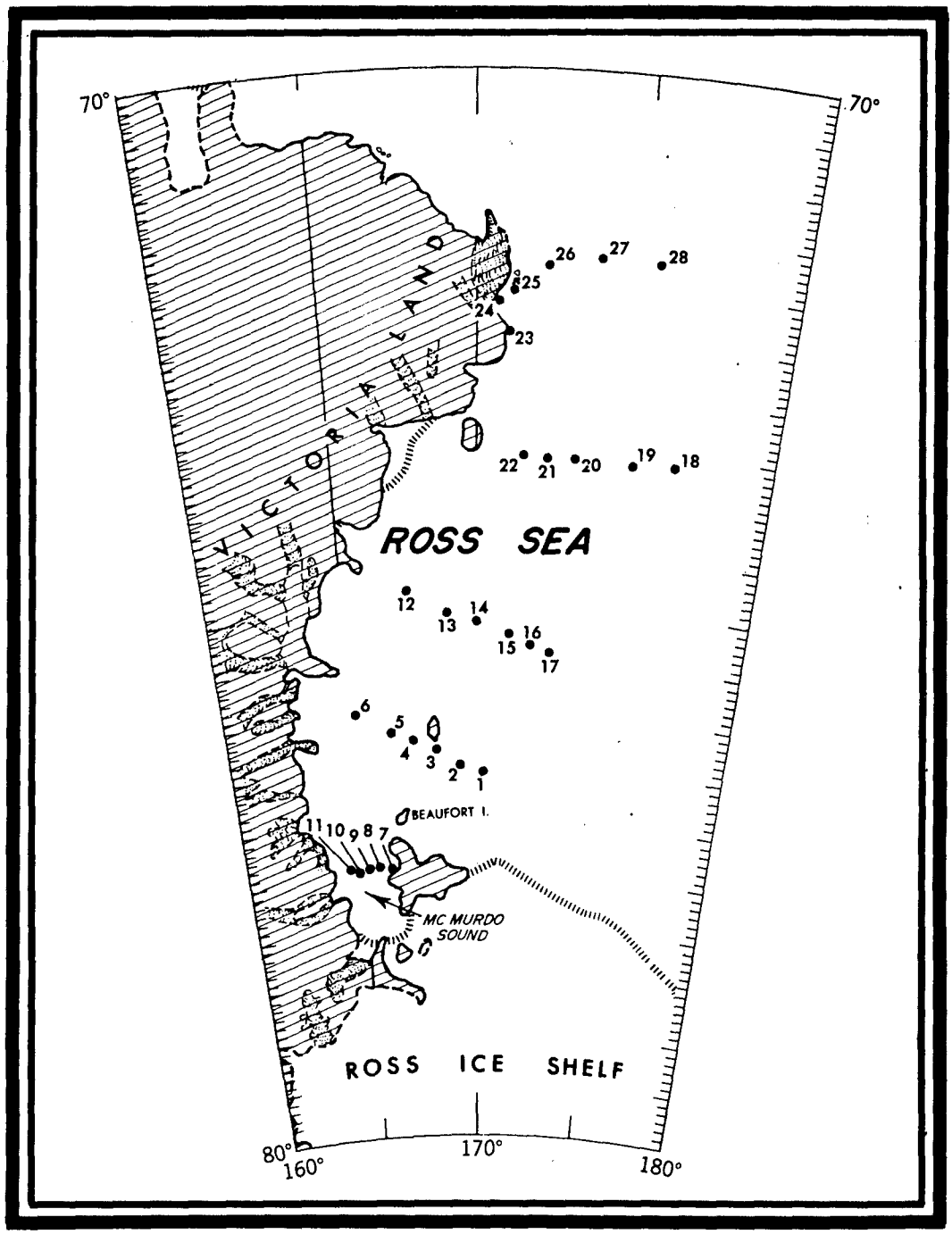


FIGURE 2. NANSEN CAST STATION LOCATIONS

C. Currents.

1. Current Meter Measurements. Self-contained current meter arrays were moored at seven locations in the McMurdo Sound area (Fig. 1 and Table II). Each array consisted of the following:

a. A 500-or 1000-lb net buoyancy subsurface float.
b. 9/16-inch, 2-in-1, Samson braided nylon mooring line.
c. Three Geodyne model A-101 self-contained current meters spaced along the array.
d. One or two Geodyne model 855 timed release mechanisms.

The current meters were preset to record current speed and direction for a 50-second period every 10 minutes.

TABLE II. LOCATIONS OF CURRENT METER ARRAYS

Array Number	Position	Geographic Location
1	77°51'47.5" S 166°38'14.0" E	Cape Armitage
2	77°41'20" S 165°07'10" E	Daily Islands
3	77°26.9' S 164°35.0' E	Cape Bernacchi
4	77°48.1' S 166°37.2' E	Hut Point/Turtle Rock
5	77°37.8' S 166°20.7' E	North Bay/Cape Evans
6	77°33.9' S 166°10.6' E	Backdoor Bay/Cape Royds
7	77°27.9' S 169°33.1' E	Cape Crozier (This array was not recovered)

2. Parachute Drogue Measurements. Parachute drogue arrays were used to measure surface and subsurface currents. The drogue arrays were assembled with the following:

a. A styrofoam surface float.
b. A 10-foot high aluminum pole with a radar reflector and/or an identification flag.
c. Cinder blocks to counterbalance the float and to sink the drogue.
d. A 28-foot diameter parachute.
e. 5/32-inch wire rope to suspend the parachute from the surface float.

The parachute was sent to depth in a closed and upside down position. At depth, the weight of the cinder blocks parted a cardboard link, thereby releasing the apex of the parachute and enabling the parachute to open. The cardboard link method was not used for launching the surface drogues. The drogues were tracked at regular intervals, and radar fixes were made on prominent land features along the coast to determine the drift of the drogues.

The basic data reduction of the drogue measurements consisted of (1) determining the drogue's course between two fixes using a protractor and (2) calculating the speed by measuring the distance traveled and dividing by the time between the fixes. To compensate for the drag on the surface float and wire, a correction was made using the following equation:

$$V_d = V - (V_s - V)\left(\frac{C_s A_s}{C_d A_d}\right)^{\frac{1}{2}} \qquad (1)$$

(Knauss, 1963)

C_s = non dimensional drag coefficient of surface float.
C_d = non dimensional drag coefficient of drogue.
V = measured velocity of drogue system.
V_s = surface velocity. (This value was assumed to be the speed of the surface drogue.)
V_d = drogue velocity.
A_s = cross sectional area of float and the cross sectional area of half the length of wire used to suspend the drogue.
A_d = adjusted cross sectional area of the parachute canopy and the cross sectional area of half the length of wire used to suspend the drogue. The adjusted cross sectional area equals two-thirds of the actual area of the drogue.

Equation (1) is derived by equating the drag forces on the wire, surface float, and drogue. This equation can be simplified by assuming that half the cross sectional area of the wire is associated with the float area and the other half with the drogue area, and by assuming that the drag coefficients of the float, wire, and drogue

are equal. Hence, equation (1) reduces to:

$$V_d = V - (V_s - V)\left(\frac{A_s}{A_d}\right)^{\frac{1}{2}} \qquad (2)$$

In applying equation (2), the north and east components of the measured velocity of the drogue system are determined first. Equation (2) is then separately applied to the north and east components. The corrected north and east components then are vectorially added to obtain the corrected drogue velocity.

D. Salinity.

Salinities were determined with either an Industrial Instruments Model RS-7B or a Bissett-Berman Model 6220 inductive salinometer. The salinometers were standardized with Copenhagen water before each series of determinations (10 to 15 samples). Substandard water with a salinity of 37.376 °/₀₀ was occasionally analyzed to ensure that the salinometers were accurate. In addition, a sample from a previous series was often analyzed to check the precision of the instruments. On the basis of these checks, the accuracy of the salinity analyses is believed to be $\pm$0.02 °/₀₀ or better.

V. DISPOSITION OF DATA

Results of all current meter and parachute drogue measurements are on file at NAVOCEANO. A vector analysis of the current drogue data is presented in the Appendix. All oceanographic station data and BT data will be on file at the National Oceanographic Data Center (NODC).

VI. PRELIMINARY ANALYSES

A. Temperature and Salinity.

The oceanographic data collected at the ice forecast stations are summarized in Table III, and cross sections constructed from these data are presented in Figures 3 through 7. A detailed discussion will not be attempted here, but a few features of the cross sections will be pointed out to help summarize the data.

Antarctic Surface Water was encountered at all stations, but Winter Water was never encountered. This absence of Winter Water is not too surprising since the observations were made near the end of the summer season. Circumpolar Water was encountered only at some of the most northerly stations (stations 26, 27, and 28), but its influence is indicated at stations farther south by the temperature maximum shown in Figure 6. The possibility exists that the other areas of relatively high temperatures also reflect the influence of Circumpolar Water. Shelf Water was present at all stations in

TABLE III. OCEANOGRAPHIC STATION SUMMARY

Consec. Sta. Number	Latitude °S	Longitude °E	Sonic Depth (Meters)	Cast Depth (Meters)	BT	Salinity and Temperature
1	76°32'	170°28'	713	369	√	√
2	76°27'	169°15'	705	641	√	√
3	76°19'	168°04'	658	650	√	√
4	76°14'	167°24'	677	635	√	√
5	76°08'	166°29'	658	570	√	√
6	75°56'	165°06'	860	562	√	√
7	77°27'	166°05'	785	325	√	√
8	77°27'	165°39'	878	469	√	√
9	77°26'	165°20'	732	508	√	√
10	77°28'	164°52'	365	297	√	√
11	77°24'	164°24'	180	175	√	√
12	74°50'	167°18'	695	500	√	√
13	75°03'	168°56'	326	283	√	√
14	75°08'	170°00'	686	372	√	√
15	75°15'	171°00'	549	466	√	√
16	75°20'	171°53'	560	464	√	√
17	75°25'	172°44'	695	461	√	√
18	73°38'	176°45'	521	444	√	√
19	73°37'	175°18'	435	434	√	√
20	73°36'	173°20'	300	300	√	√
21	73°36'	172°22'	448	384	√	√
22	73°35'	171°30'	530	500	√	√
23	72°26'	170°56'	292	*	√	√
24	72°10'	170°40'	360	350	√	√
25	72°04'	171°06'	320	257	√	√
26	71°48'	172°08'	814	516	√	√
27	71°45'	173°52'	2012	577	√	√
28	71°45'	175°30'	2195	600	√	√
				* Possible Post Trips		

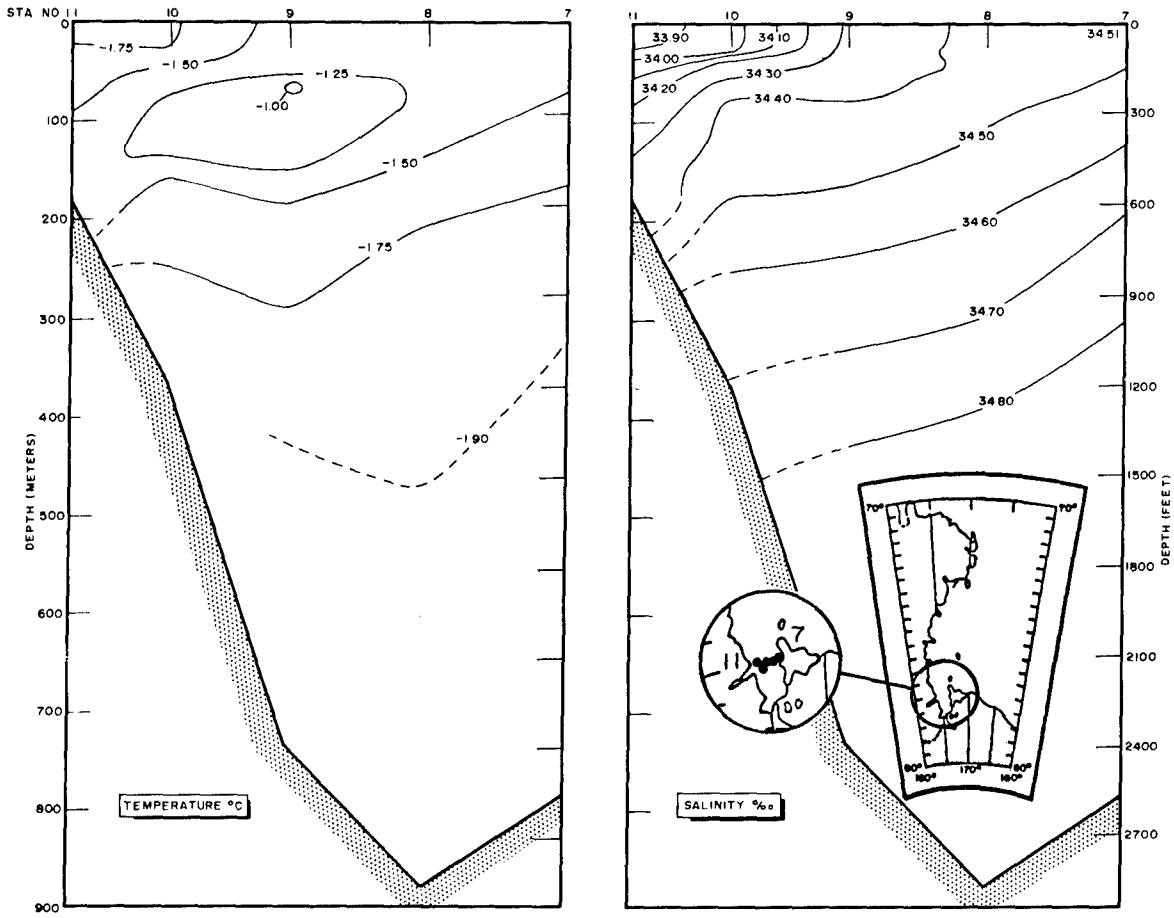


FIGURE 3. TEMPERATURE AND SALINITY CROSS SECTIONS - STATIONS 11 TO 7

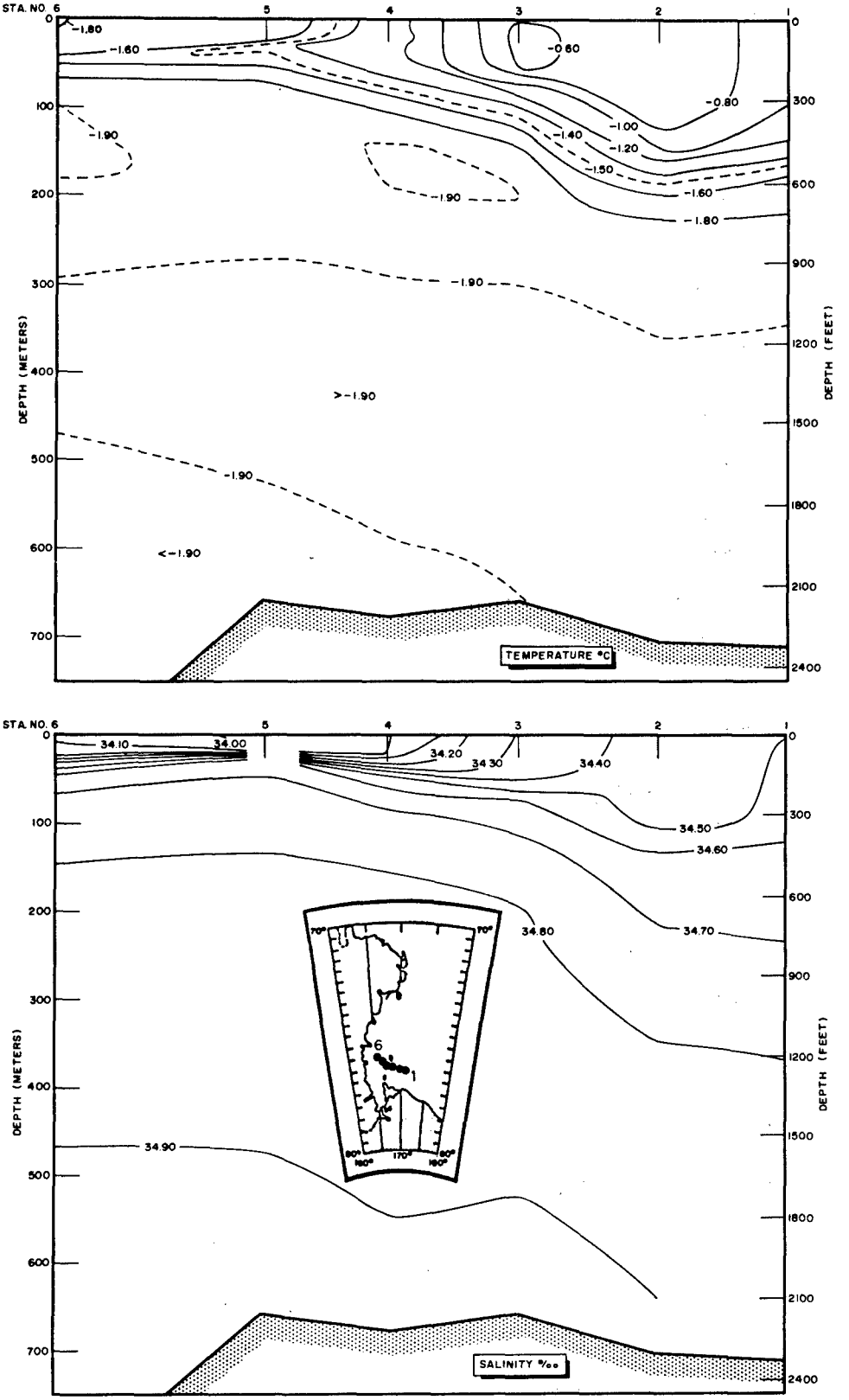


FIGURE 4. TEMPERATURE AND SALINITY CROSS SECTIONS STATIONS 6 TO 1

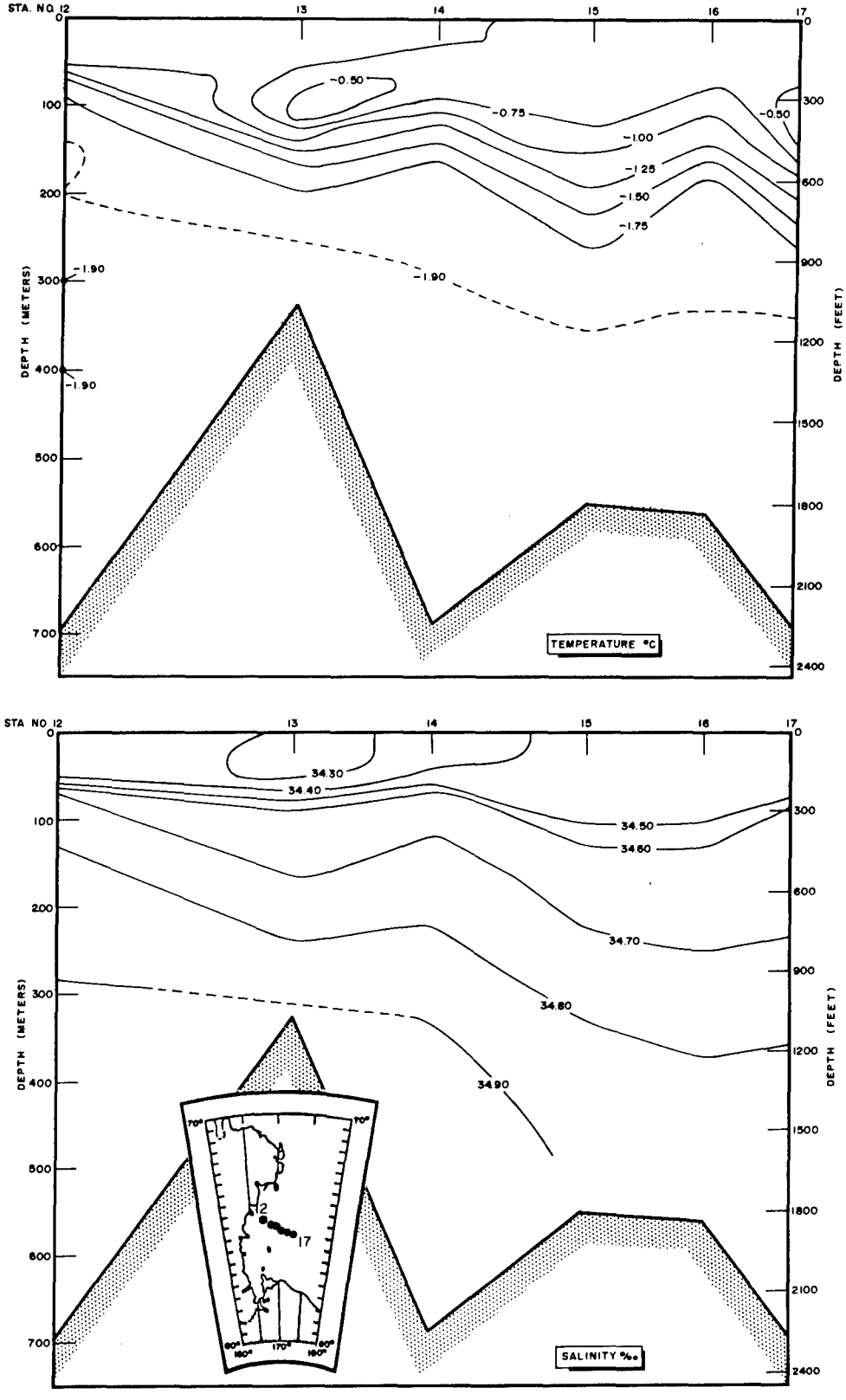


FIGURE 5. TEMPERATURE AND SALINITY CROSS SECTIONS STATIONS 12 TO 17

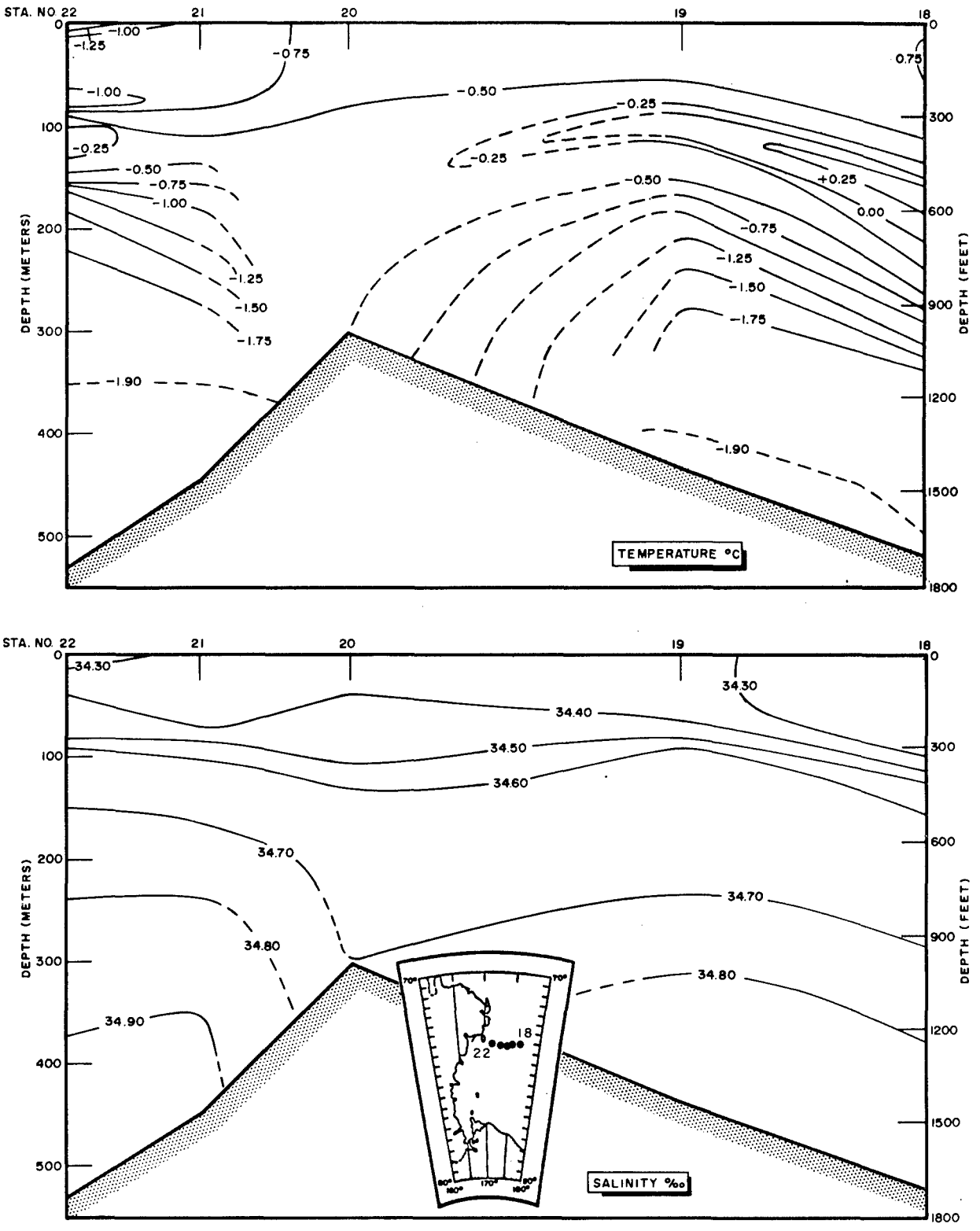
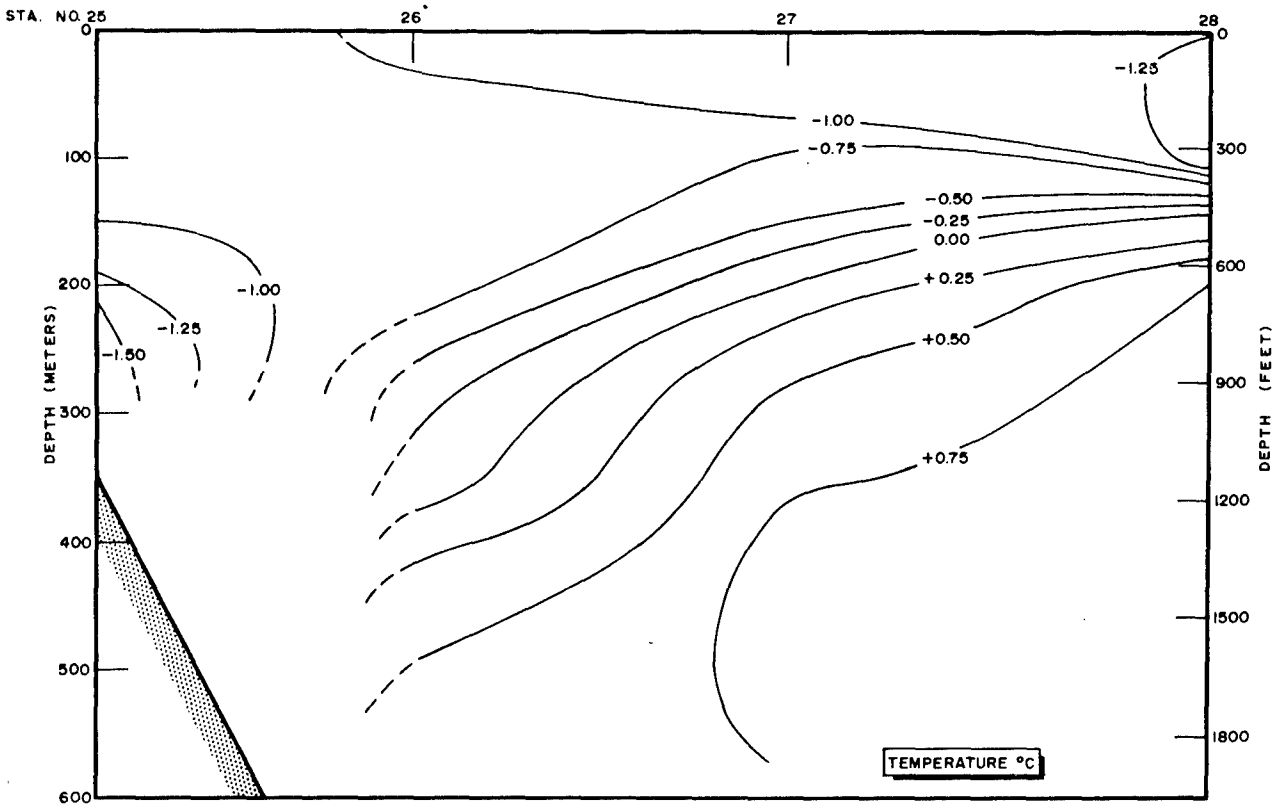


FIGURE 6. TEMPERATURE AND SALINITY CROSS SECTIONS - STATIONS 22 TO 18



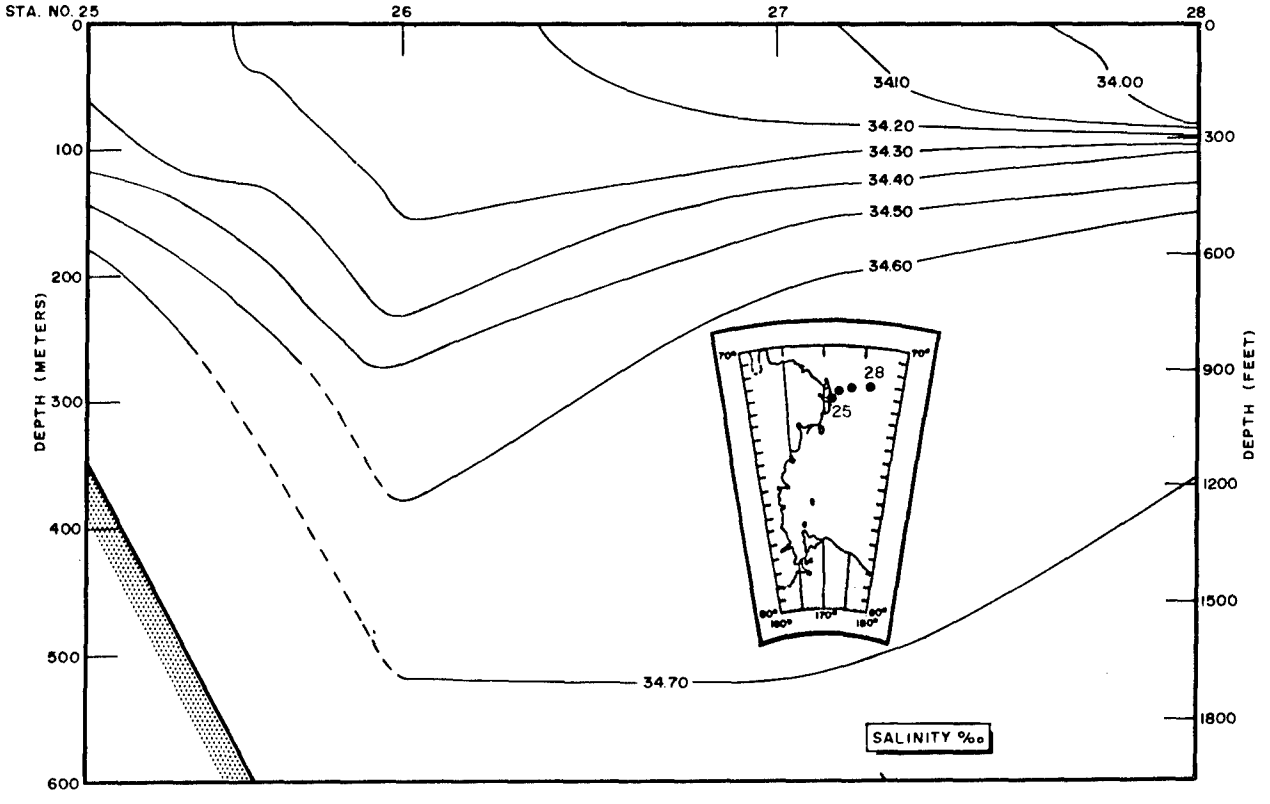


FIGURE 7. TEMPERATURE AND SALINITY CROSS SECTIONS - STATIONS 25 TO 28

the four southernmost cross sections (Figs. 3-6) except at station 20.

In Figure 6, the shapes of the isopleths near station 20 seem to indicate that the deeper waters are in a basin and are isolated from free interchange with the deeper waters at neighboring stations; however, more information is needed to verify this hypothesis.

B. Currents.

In discussing the drogue measurements, it should be pointed out that the tidal cycles in McMurdo Sound have a strong diurnal component, and that the tracking period for all drogue measurements was less than 24 hours. Furthermore, it is not known whether the drogue reached the desired depth or that the parachute fully opened.

In general, the average drifts of the drogues agreed with the current scheme presented in H.O. Pub. No. 27; however, two exceptions were noted: (1) a southwest drift into New Harbor contrasted with the northwest drift described in Pub. 27; and (2) a southerly drift extended as far south as Inaccessible Island which indicated that the Cape Bird Current may have been leaving the coast farther south than described in Pub. 27. In a number of cases, there appeared to be some correspondence between current and wind direction.

The drogue measurements made near Cape Armitage, Hut Point, and Turtle Rock indicated a northwesterly flow, which is in conformity with both Pub. 27 and the measurements made by Gilmour (1963) at a station 8 miles north-northeast of Cape Armitage, but they do not agree with numerous observations (especially at depth) of flow towards the Ross Ice Shelf at stations on fast-ice near Cape Armitage. Differences in geographical positions could be the cause of the apparent disagreement between these flows, and the possibility exists that a current could split near Cape Armitage with part of it setting to the northwest and the other part setting towards the ice shelf. However, better knowledge of the current regime is necessary before this question can be resolved.

VII. ADDITIONAL WORK NEEDED IN THE REGION

Long term current measurements are needed at points near the Ross Ice Shelf to help define the movement of the water under the ice. Such measurements also must be made throughout the Ross Sea to adequately describe the current regime.

Temperature and salinity data should be collected on a continuing basis for long term ice prediction.

Further analysis of data already collected would substantially add to our knowledge of the oceanography of this region.

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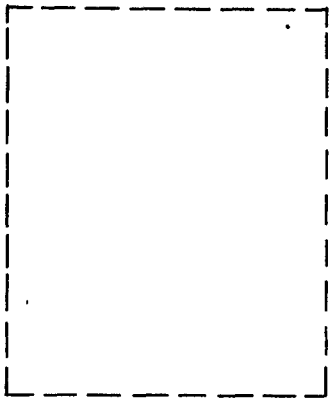
APPENDIX

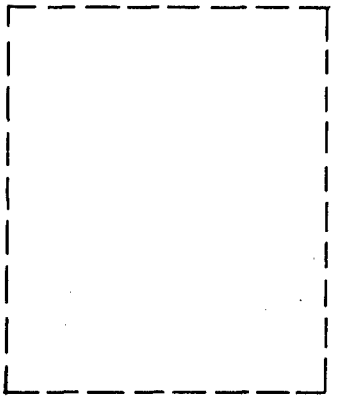
Vector Analyses of Parachute Drogue Data



Location : New Harbor (Marble Point to Cape Bernacchi)
Wind : Southerly at 3 to 8 knots

Drogue Depth	Date/Start Time*	Duration of Obs.	Max. Vel.
Shallow: 30 ft	15 Feb/1542	5.25 hrs	1.00 kns 182°T
Medium: 350 ft	15 Feb/1600	5.00 hrs	0.90 kns 164°T
Deep: 700 ft	15 Feb/1607	5.00 hrs	1.30 kns 298°T

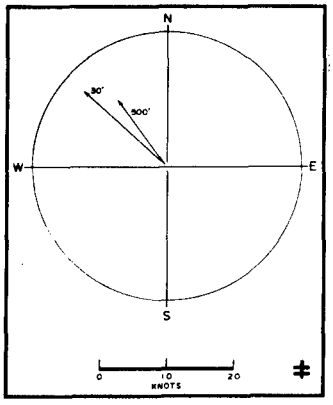
Comments: Ice drifted into the survey area during the tracking period. The drogues released in this area drifted southwest into the ice. Due to the interference on the drogue trajectory from the ice, drag corrections and mean velocity vectors were not calculated.



Location : Daily Islands
Wind : Southeasterly at 18 to 20 knots

Drogue Depth	Date/Start Time	Duration of Obs.	Max. Vel.
Shallow: 30 ft	16 Feb/0018	3.5 hrs	1.40 kns 110°T
Medium: 550 ft	16 Feb/0032	7.0 hrs	1.00 kns 232°T
Deep: 1000 ft	16 Feb/0046	3.0 hrs	0.63 kns 121°T

Comments: Both shallow and medium drogues fouled in ice. During the initial three hours, the drogues drifted in a southwest direction; however, the medium drogue, which was re-visited seven hours after release, indicated a current reversal in the northwest direction. Due to ice interference, drag corrections and mean velocity vectors were not calculated for these trajectories.



Mean Corrected Velocities

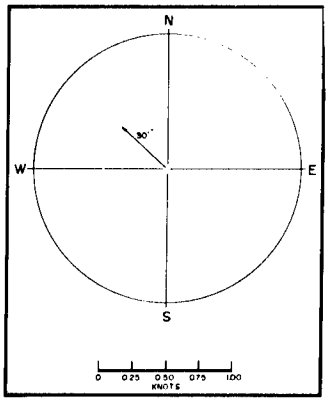
Location : Marble Point
Wind : Southeasterly at 26 to 31 knots

Drogue Depth	Date/Start Time	Duration of Obs.	Max. Vel.
Shallow: 30 ft	16 Feb/1010	5.00 hrs	2.21 kns 313°T
Deep: 500 ft	16 Feb/1034	5.25 hrs	1.26 kns 304°T

Comments: Since ice interfered with the drogue measurements in New Harbor, drogues were re-launched farther offshore. Both drogues indicated a northwesterly flow out of McMurdo Sound.

* All times in the Appendix are in local New Zealand time (-12 zone)

≠ Note scale changes from diagram to diagram

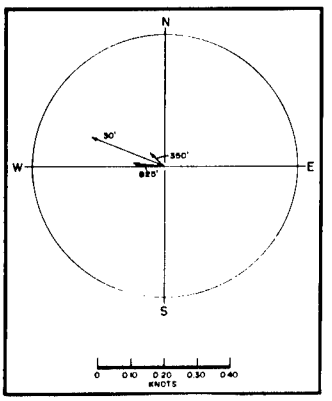


Mean Corrected Velocities

Location : Cape Armitage/Hut Point
Wind : Easterly, shifting to southeasterly at 8 to 20 knots

Drogue Depth	Date/Start Time	Duration of Obs.	Max. Vel.
Shallow: 30 ft	17 Feb/0615	16.4 hrs	1.04 kns 344°T
Deep: 200 ft	17 Feb/0640	1.5 hrs	1.45 kns 328°T

Comments: Ice interfered with the drift of the deep drogue 1.5 hours after release. The average corrected drift for the deep drogue during this initial period was 0.78 knots at 323°T.. Since the shallow drogue was tracked for almost 15 hours longer than the deep drogue, the computed average drift for both drogues cannot be compared. During the tracking period, a tidal reversal of the Cape Armitage-Hut Point Current was not observed.

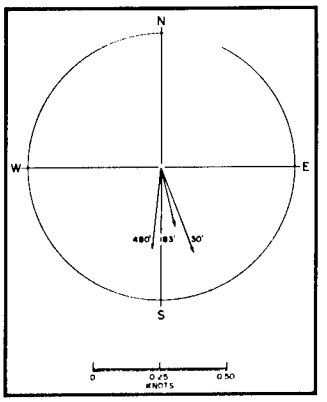


Mean Corrected Velocities

Location : Hut Point/Turtle Rock
Wind : Easterly, shifting to southeasterly at 8 to 20 knots

Drogue Depth	Date/Start Time	Duration of Obs.	Max. Vel.
Shallow: 30 ft	17 Feb/0915	12.8 hrs	0.67 kns 296°T
Medium: 350 ft	17 Feb/0925	13.0 hrs	0.35 kns 286°T
Deep: 825 ft	17 Feb/0954	12.5 hrs	0.50 kns 277°T

Comments: The medium depth drogue became temporarily fouled in ice six hours after release; however, the standard drag correction was applied to this drogue. All drogues drifted in a northwest direction; the shallow drogue, however, had an initial southerly set.

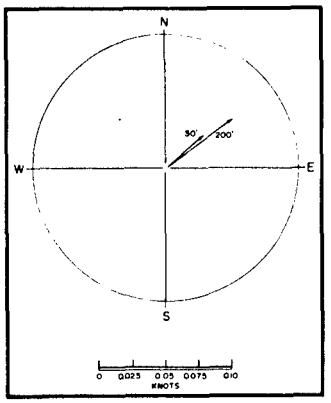


Mean Corrected Velocities

Location : Cape Evans, Barne Glacier
Wind : Southeasterly at 0 to 16 knots

Drogue Depth	Date/Start Time	Duration of Obs.	Max. Vel.
Shallow: 30 ft	18 Feb/0045	9.30 hrs	0.70 kns 157°T
Medium: 183 ft	18 Feb/0053	9.75 hrs	0.76 kns 201°T
Deep: 480 ft	18 Feb/0100	11.00 hrs	1.55 kns 143°T

Comments: The drogues were launched in the southerly extension of the Cape Bird Current. At the last navigational fix, the shallow drogue appeared to be heading between Cape Evans and Inaccessible Island, while the medium and deep drogues drifted past the western side of Inaccessible Island.

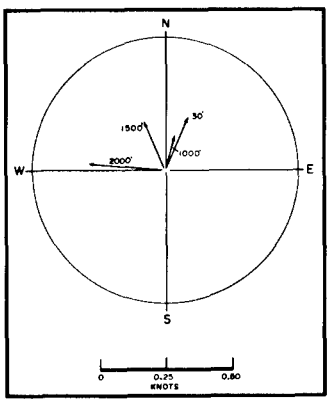


Mean Corrected Velocities

Location : Cape Royds
Wind : Southerly at 0 to 15 knots

Drogue Depth	Date/Start Time	Duration of Obs.	Max. Vel.
Shallow: 30 ft	18 Feb/1247	10.7 hrs	0.42 kns 345°T
Deep: 200 ft	18 Feb/1253	10.5 hrs	0.42 kns 004°T

Comments: Both drogues were launched at the mouth of Backdoor Bay and remained in the Bay during the tracking period. Due to the large variation in drift direction, the computed average drift vectors are small as compared to the individual velocities.



Mean Corrected Velocities

Location : Cape Crozier
Wind : Southerly at 10 to 26 knots

Drogue Depth	Date/Start Time	Duration of Obs.	Max. Vel.
Shallow: 30 ft	19 Feb/0743	16.3 hrs	0.56 kns 022°T
Medium: 1000 ft	19 Feb/0822	15.7 hrs	1.16 kns 355°T
Medium: 1500 ft	19 Feb/1530	9.0 hrs	1.83 kns 337°T
Deep: 2000 ft	19 Feb/0856	15.0 hrs	0.95 kns 242°T

Comments: The shallow and medium drogues drifted in a northerly direction, indicating an apparent outflow from under the Ross Ice Shelf. The deep drogue, however, had an initial southwest drift before turning to the northwest.

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13. ABSTRACT

During February 1968, a two-phase operation was conducted in Antarctica by NAVOCEANO personnel. The first phase was a study of the currents in the McMurdo Sound region, and the second phase consisted of occupying the annual ice potential stations in the Ross Sea in support of NAVOCEANO's Antarctic Ice Prediction Program.

Current measurements were made by tracking drogues and by mooring self-contained current meter arrays. Preliminary analysis of the drogue data indicates that currents in McMurdo Sound conform generally with the scheme outlined in H.O. Pub. 27 except for a southwest instead of a northwest drift into New Harbor. The data also indicate that the Cape Bird current may have been leaving the coast farther south than described in H.O. Pub 27.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
OCEANOGRAPHY						
ROSS SEA, ANTARCTICA						
PARACHUTE CURRENT DROGUES						
CURRENT METER ARRAYS						
USCGC WESTWIND (WAGB 281)						
USCGC BURTON ISLAND (WAGB 283)						